MAR 8 1982

92.G-25 TD 240.55-1

U.S. Department
of Transportation
Federal Highway Administration

Demonstration Projects
Program

Demonstration Project No. 55

Asphalt Emulsions for Highway Construction

Plymouth Township

ORIGINAL

COMPLETED

30

FHWA-DP-55-1

Initial Report

January 1982

I

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation. The United States Government assumes no liability for the contents or use thereof.

Additional copies may be obtained by contacting:

Federal Highway Administration
Demonstration Projects Division
1000 North Glebe Road
Arlington, Virginia 22201

Telephone: 703-557-0522

BITUMINOUS SEAL COAT USING PRECOATED AGGREGATE

INITIAL EVALUATION REPORT

FHWA DEMONSTRATION PROJECTS DIVISION

WORK ORDER NO.: DTFH 71-80-55-PA-01

BY

CHARLES F. OYLER, P. E.

DIRECTOR OF PUBLIC WORKS

PLYMOUTH TOWNSHIP

NORRISTOWN, PENNSYLVANIA

CONDUCTED IN COOPERATION WITH

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

NOVEMBER, 1980

III

PLYMOUTH TOWNSHIP

MONTGOMERY COUNTY, PENNSYLVANIA

BITUMINOUS SEAL COAT USING PRECOATED AGGREGATE

EVALUATION PLAN

I OBJECTIVE

The objective of this project was to collect information on the design, construction and performance of a bituminous seal coat using precoated aggregate.

II DESCRIPTION OF WORK

This demonstration project includes a preconstruction evaluation, design and construction of a bituminous seal coat using precoated aggregate which was comprised of an asphalt emulsion.

Approximately 50,000 square yards of residential streets in different locations of the Township were surface treated and evaluated.

III PRECONSTRUCTION EVALUATION

See Table No. 1.

IV DESIGN CRITERIA

A. The objective of the surface treatment is to provide a low cost, all weather, waterproof surface, to a dry weathered surface, while at the same time providing a skid resistant surface.

B. The type of surface treatment selected was a single treatment of Bituminous Seal Coat using ½" precoated aggregate.

C. In determining the type and grade of asphalt emulsion and aggregate material used, the following design principles were considered:

(1) When one size cover aggregate is dropped by a spreader on an asphalt film, the particles lie in unarranged positions and the voids between the particles are approximately 50 percent.

(2) Rolling shifts the aggregate particles and the voids are reduced to 30 percent.

(3) Finally, after considerable traffic, the particles become oriented into their densest positions, with all lying on their flattest sides, and the voids become approximately 20 percent.

(4) Since the particles lie on their flattest sides, the average thickness of a surface treatment is determined from the overall average smallest dimension of the aggregate particles.

(5) The average least dimension of any approximately one-size cover aggregate can be determined by calipering a number of individual aggregate particles or by using slotted screens.

TABLE NO. 1 - PRECONSTRUCTION EVALUATION

	CROSS-SECTIONAL INFORMATION			RECENT MAINTENANCE HISTORY	ACCIDENT DATA		CLIMATIC CONDITIONS	DRAINAGE CHARACTERISTIC
	SUBBASE AND/OR BASE	WEARING SURFACE	SURFACE CONDITION		NUMBER (ANNUAL)	SKID RESISTANCE LEVEL (SRL)		
Valley Creek Rd. - Bell Rd. - Skip Rd.	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1972 Slurry Seal	1	L	Warm, humid summers, moderately mild winters and ample rainfall. Average daily temperatures range from 40 degrees in January to 87 degrees in July. Approximately 42 inches of precipitation annually. Frost line at 30 inches below grade.	Good Crown Existing Storm Sewers
Kormar Rd. - Valley Creek Rd. - Skip Rd.	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1972 Slurry Seal	0	L		Good Crown Existing Storm Sewers
Skip Rd. - Church Rd. - End	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1972 Slurry Seal	0	L		Good Crown Existing Storm Sewers
Church Rd. - Valley Creek Rd. - End	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1972 Slurry Seal	0	L		Good Crown Existing Storm Sewers
Brighton Rd. - Sheffield Dr. - Church Rd.	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1972 Slurry Seal	0	L		Good Crown Existing Storm Sewers
Meredith La. - Sheffield Dr. - Runnymede Dr.	8" Stone Base	2½" ID-2A Bit. Surf. Crse.	Reflection, Shrinkage & Alligator Cracks	1970 FJ-2	0	L		Good Crown Existing Storm Sewers
Runnymede Dr. - Sheffield Dr. - Knoll Rd.	8" Stone Base	2½" ID-2A Bit. Surf. Crse.	Reflection, Shrinkage & Alligator Cracks	1970 FJ-2	0	L		Good Crown Existing Storm Sewers
Launfall Rd. - Germantown Pk. - Camelot Dr.	8" Stone Base	2" HE - 1 Bit. Surf. Crse.	Slippage & Shrinkage Cracks, Depressions	1970 FJ-2	3	L		Good Crown Existing Storm Sewers
Camelot Dr. - Lancelot Rd. - Red Rowan La.	8" Stone Base	2" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks	1970 FJ-2	0	L		Good Crown Existing Storm Sewers
Red Rowan La. - Gawain Rd. - Cul-de-sac	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks Utility Cut Depressions	1970 FJ-2	1	L		Good Crown Existing Storm Sewers
Blue Ridge Rd. - Sierra Rd. - Shasta Rd.	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1973 Slurry Seal	0	L		Good Crown Existing Storm Sewers
Rainier Rd. - Sierra Rd. - Blue Ridge Rd.	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1973 Slurry Seal	0	L		Good Crown Existing Storm Sewers
Black Hill Rd. - Sierra Rd. - Blue Ridge Rd.	8" Stone Base	3" HE - 1 Bit. Surf. Crse.	Alligator & Shrinkage Cracks, Depressions	1973 Slurry Seal	0	L		Good Crown Existing Storm Sewers
Karrs La. - Butler Pk. - End	No Base	Penetration Surf. Crse.	Raveling, Shrinkage & Alligator Cracks Utility Cut Depressions	1966 HE Overlay	2	L		Poor Crown Lacking Adequate Storm Sewers

-More-

BEST DOCUMENT AVAILABLE

BEST DOCUMENT AVAILABLE

TABLE NO. 1 - PRECONSTRUCTION EVALUATION

	TRAFFIC DATA			ROADWAY GEOMETRICS				
	ADT	% TRUCKS	SPEED LIMIT	GROWTH RATE	CROSS SECTION	LENGTH	WIDTH	GRADES, % SLOPE
Valley Creek Rd. - Bell Rd. - Skip Rd.	150	10	25 MPH	Increasing	3/16"/ft.	1350'	27'	1%-2.8%
Kormar Rd. - Valley Creek Rd. - Skip Rd.	75	8		Increasing	3/16"/ft.	1550'	26'	0.7%-5%
Skip Rd. - Church Rd. - End	60	8		Increasing	3/16"/ft.	790'	26'	2.8%-4.6%
Church Rd. - Valley Creek Rd. - End	75	12		Increasing	3/16"/ft.	2070'	26'	0.4%-4%
Brighton Rd. - Sheffield Dr. - Church Rd.	80	8		Increasing	3/16"/ft.	300'	27'	0.5%-1%
Meredith La. - Sheffield Dr. - Runnymede Dr.	75	5		QUO	1/4"/ft.	1000'	27'	3%-5%
Runnymede Dr. - Sheffield Dr. - Knoll Rd.	85	5		QUO	1/4"/ft.	1690'	27'	1%-3%
Launfall Rd. - Germantown Pk. - Camelot Dr.	300	15		Increasing	3/16"/ft.	854'	34'	3%
Camelot Dr. - Lancelot Rd. - Red Rowen La.	100	8		QUO	3/16"/ft.	510'	27'	11%
Red Rowen La. Gawain Rd. - Cul-de-sac	200	10		QUO	3/16"/ft.	1300'	27'	1%
Blue Ridge Rd. Sierra Rd. - Shasta Rd.	95	10		QUO	3/16"/ft.	890' / 1000'	34' / 27'	3%-4%
Rainier Rd. - Sierra Rd. - Blue Ridge Rd.	70	8		QUO	3/16"/ft.	750'	27'	2%-3%
Black Hill Rd. - Sierra Rd. - Blue Ridge Rd.	70	8		QUO	3/16"/ft.	1150'	27'	2%-4%
Karrs Lane - Butler Pk. to End	125	12		Increasing	1/8"/ft.	1055'	24'	0.5%-5%

BEST DOCUMENT AVAILABLE

With these principles in mind a PennDOT Classification E-3 emulsion (AASHTO - CRS - 2) was chosen for the seal coat and an E-1 emulsion (AASHTO - RS - 1) was selected to coat the aggregate. The selection of these types of emulsions enabled us to cover the surface uniformly without putting in depressions or running off the crown at grade, cure and develop adhesion quickly and hold the aggregate tightly to the road surface without dislodging by traffic.

D. The aggregate chosen had to be hard, clean, uniform in size, cubical instead of flat or elongated. A ½" aggregate was selected to reduce the noise or rumble and dislodging from the seal coat.

Specific data for the aggregate used in this project included the following:

Supplier	-	General Crushed Stone Rockhill Township Plant Bucks County, Pennsylvania
Type	-	Diabase (Basalt) - Trap Rock
Specific Gravity		3.03
Absorption	-	.37
SRL	-	"H"

Ave. Gradation	Sieve	% Passing
	3/8"	100
	#4	60
	#8	6
	200	1

E. The E-3 and E-1 emulsions selected to be used in the surface treatment program have the following physical properties:

E-3 Emulsion (Seal Coat)

Residual Asphalt Content	-	68%
Viscosity	-	121 Saybolt Furol Seconds at 122° F.
Demulsibility	-	75%
Adhesion	-	98%
Specific Gravity	-	1.012 @ 60° F.
Penetration	-	138 @ 77° F.
Density	-	8.428 lbs./gallon @ 60° F.

E-1 Emulsion (Precoating)

Residual Asphalt Content	-	62%
Viscosity	-	25 Saybolt Furol Seconds @ 77° F.
Demulsibility	-	75%
Adhesion	-	Not Available

BEST DOCUMENT AVAILABLE

E-1 Emulsion (Precoating) continued

Specific Gravity	-	1.010 @ 60° F.
Penetration	-	150 @ 77° F.
Density	-	8.413 lbs./gallon

(1) Source of Base Asphalt for both emulsions - Boscan Crude Venezuela.

(2) Percent Solvent in both emulsions - none.

(3) Type and Concentration of Emulsifying Agent (based on weight of emulsion).

E-3 Emulsion - .32% Catamuls 301 (Amine)
.15% Hydrocloric Acid

E-1 Emulsion - .20% Oleic Acid
.05% Sodium Hydroxide

F. Design Procedure .

(1) The aggregate spread rate was determined by the Pennsylvania Design Method of Seal Coats and Surface Treatments as given in the Pennsylvania Department of Transportation Bulletin 27. The spread rate is dependent upon the gradation of the aggregate and was plotted on Charts No. 1 and 2. The resultant aggregate spread rate was 13.5 lbs./square yard.

(2) Precoating the aggregate with a very thin layer of emulsion prevented any dust problem and provided good adhesion of the seal coat to the aggregate. The aggregate was run through an asphalt mixing plant dryer, cooled to a temperature not exceeding 150°F., then mixed in a pugmill with 0.5 to 1.0 percent E-1 emulsion to coat each particle thoroughly. The mixing time in the pugmill was not less than 30 seconds. This small amount of emulsion did not change the aggregate from a free flowing material which could still be stockpiled, handled and applied uniformly with a self-propelled spreader.

(3) The asphalt spread rate and temperature was also determined by using the Pennsylvania Design Method of Seal Coats and Surface Treatments as described in the Pennsylvania Department of Transportation Bulletin 27. The spread rate is dependent upon the gradation of the aggregate, the average daily traffic using the roadway and the existing surface condition of the roadway. These factors were plotted on Chart 1, Chart 3 and Chart 4. The resultant asphalt spread rate was 0.24 gallons per square yard at 160° F..

(4) Field tests and analyses were conducted by Plymouth Township, its contractors and the Pennsylvania Department of Transportation to determine the correct design and construction procedures over a period of the last seven years. As a result, this year's program was the most successful so far based on the amount of

aggregate spread and amount of aggregate retained on the roadway surface after a period of one week. Other laboratory tests were conducted on the asphalt emulsion including a stripping test, Static-Immersion Test, and Stone Coating Test (Dry and Wet Reference Aggregate) to determine the coating characteristics of the material.

G. Traffic Control Plan. In order to complete any type of roadway surface work, it is imperative that all parked vehicles be removed from the street. In our case, this was a two step process. Approximately one month prior to the surface treatment, our police notified all property owners with disabled vehicles or vehicles without current registration plates to have them remove the vehicles in front of their respective homes within ten days.

Twenty-four hours prior to the work, all residents living on the streets to be treated, were given written notification that the next day their street was to be surface treated and they should remove all cars from in front of their home. This type of notification was successful and the residents were very cooperative. Only one vehicle had to be moved prior to the construction.

During the surface treatment operation, traffic was detoured onto other local streets. Public Works Department personnel were stationed at both ends of the street to detour traffic and help motorists unfamiliar with the area to find alternative routes.

Public pressure did not permit us to close the road for any extended period of time. Therefore, once the work was completed and initial asphalt set had occured, traffic was permitted on the street at a controlled speed of 15 MPH. Once again, flagmen were used to slow down traffic. This procedure curtailed the whipping off of aggregate and damage to the paint finish on the vehicles. After the final set had occurred, an hour or two later, the roadway was opened to uncontrolled traffic.

This limited closure of the street is one of the benefits of this type of surface treatment. Residents do not like to be restricted in the use of their vehicles and unlike a slurry seal treatment which requires closing the street for four to six hours, the inconvenience occurs only during the application and rolling of the aggregate.

Traffic control was also extended to the hauling of equipment. The aggregate trucks were routed to the aggregate spreader in a direction opposite to the progress of the surface treatment operation. This prevented them from turning on the freshly placed treatment. Trucks were then required to turn around at a designated spot away from the new work for their return trip to the stockpile.

H. Job Specifications. A complete set of job bid documents including specifications are attached as Exhibit "A".

V CONSTRUCTION CRITERIA/PROCEDURES

A. Repair and Conditioning of Existing Surfaces. Given the surface conditions encountered in III-Preconstruction Evaluation, the following repairs were made to the existing street surfaces:

(1) Alligator Cracks - scoured area around cracking, around unsuitable materials and backfilled with Modified 2B stone, seven inches of bituminous base course and one inch of ID-2A wearing course.

(2) Shrinkage Cracks - no special repair was made of these cracks since the surface treatment emulsion should fill in and seal them.

(3) Depressions - leveled with ID-2A wearing course.

(4) Slippage Cracks - removed the slipped layer from around the crack to a point where good bond between the layers is found and patched with ID-2A wearing course.

(5) Raveling - surface treatment alone corrected this defect.

(6) Reflection Cracks - cracks less than 1/8 inch wide were ignored. Cracks wider than 1/8 inch were filled with a hot E-1 emulsion.

These repairs occurred one to two months prior to the construction to ensure proper consolidation of the patch under traffic.

Once all needed repairs were made, all vegetation was removed from the gutter line between the curb and pavement section. Then just prior to the placement of the surface treatment, the streets were swept with a three-wheel mechanical sweeper.

B. Climatic Conditions During Construction. The month of August was selected during which the surface treatment would take place due to its hot and dry weather. Care was taken to insure that the air, pavement surface, and aggregate temperatures were 50° F. or above. These precautions ensured the proper break (or set) of the emulsion. Also, work did not commence when the roadway was wet or rain was threatening. If it would have rained before the emulsion got a chance to break, the emulsion would have been diluted and would have resulted in loss of cover aggregate. High humidity would have also retarded the breaking process.

Fortunately, the four days we applied the surface treatment were relatively hot and dry as planned.

August 25, 1980 - Air Temperature 90° F. Humidity 41%
August 26, 1980 - Air Temperature 90° F. Humidity 47%
August 27, 1980 - Air Temperature 91° F. Humidity 45%
August 28, 1980 - Air Temperature 92° F. Humidity 43%

Winds were calm on all four days.

C. Noted Changes in Material Properties at Job Site.

(1) Asphalt Emulsion - When applied to the street surface, the E-3 emulsion initially appeared brown to brownish-black in color. As breaking occurred, which I will detail in Section K, the emulsion took on a darker more blackish color.

(2) Precoated Aggregate - Aggregate arrived on the job site damp and clear which retarded premature breaking of the emulsion immediately on contacting the aggregate surface. As the aggregate was spread (less than one minute after the emulsion is distributed) it was held in the emulsion. The rolling operation set the asphalt and promoted the bond, which was necessary to resist traffic stresses.

D. Asphalt Spraying Operation. Before the surface treating operation started, a line was established along the curb line to guide the driver of the distributor truck. Distributor operators carefully watched the curb line. A shield of building paper was used to protect the curb from splash or overlap.

Speed of the distributor and length of spread were determined before spraying started. Distributor speed was determined by:

$$V = 9\,Q/WA\,(1+c)$$

Where:

V = Road speed in feet per minute
Q = Spray bar output in gallons per minute
W = Spray bar width, feet.
A = Rate of application in gallons per square yard
C = Expansion coefficient resulting from heating the asphalt

$$C = \frac{T-60}{30\,(100)}$$

T = Application temperature, degrees F.

In our case:

Q = 140 gallons per minute
W = 10 feet
A = 0.24 gallons per square yard
T = 150° F.

$$C = \frac{150-60}{30\,(100)} = .03$$

$$V = \frac{9\,(140)}{10\,(0.24)\,(103)} = 510 \text{ feet per minute}$$

The length of spread per truck of aggregate was determined before beginning the project. With this parameter, we are able to total the length of spread based on the number of loaded aggregate trucks on hand at anytime during the operation. This figure is critical,

since no more asphalt could be applied than could be covered with aggregate within one minute after the application.

$$L = \frac{9T}{WA}$$

Where :

L = length of spread per truck of aggregate, feet
T = total gallons to be applied to the surface

$$= \frac{AW_A}{S}$$

W_A = Weight of aggregate in each truck, pound

A = rate of application of asphalt in gallons/sq. yard
S = spreading rate of aggregate, pound/sq. yard
W = spray bar width, feet

In our case:

W_A = 40,000 lbs.

A = 0.24 gals./sq. yd.
S = 13.5 lbs./sq. yd.
W = 10 feet

$$T = \frac{(0.24)\ (40,000)}{13.5}$$

= 711 gallons

Therefore:

$$L = \frac{9\ (711)}{(10)\ (.24)}$$

= 2666 feet/truck load

After all adjustments and checks were made to the distributor (Section 5.E) including heating the asphalt to proper spraying viscosity, the distributor was ready to apply the asphalt. The driver merely maintained the aforedetermined speed as indicated on the dial of the bitumeter.

Rough and unsightly transverse joints were avoided by starting and stopping the asphalt and aggregate spread on building paper. The paper was placed across the lane to be treated so that the forward edge was at the desired joint location. The distributor, traveling at the correct speed for the desired application rate, started spraying on the paper in order that the spray bar made a full, uniform application when it reached the exposed surface. A second length of building paper was placed across the lane at a predetermined cutoff point for the distributor. This procedure gave a straight, sharp transverse joint. After the aggregate spreader had passed over it, the paper was removed and destroyed.

For the next application, the leading edge of the paper was placed within ½ an inch of the cutoff line of the previously laid treatment. This prevented a gap between the two spreads.

To prevent aggregate from building up on the longitudinal joint, the edge of the aggregate spread coincided with the edge of the full thickness of applied asphalt. This allowed a width where asphalt was present in partial thickness that overlapped when asphalt was applied in the adjacent lane. The partial thickness was a result of the outside nozzle spray being only partially overlapped. Then, when the aggregate was spread for the full width in the next lane, there was no buildup at the joint.

E. Asphalt Distributor Data. A truck mounted Etnyre hydrostatic asphalt distributor was used in the seal coat application by our contractor, Asphalt Paving and Supply, a division of Interstate Asphalt Company of Quakertown, Pennsylvania. Important distributor data included the following:

Nozzle size	-	1/8"
Nozzle spacing	-	4"
Nozzle slot angle	-	30^{o} with Spray Bar
Coverage	-	Triple lap

Prior to the application, the spray bar height was tested to insure a uniform triple lap with all nozzles operating. First, the second and third, fifth and sixth, eighth and ninth, etc. nozzles were closed, using the center section of the bar only. The distributor was then operated at the predetermined pump pressure with the spray bar height adjusted not more than one half inch at a time. Once an even single film of asphalt, heated to the proper spraying viscosity was applied to the surface, it gave a uniform triple lap. All nozzles were opened and the bar height was set at ten inches.

To insure that the spray bar height stayed within a tolerance of one half inch while the asphalt left the distributor and the load lightened, raising the distributor, the frame of the distributor was tied down to the axle during the spreading runs.

Nozzles were checked for clogging or damage that could produce a distorted fan of asphalt.

To insure accurate registering of speeds while the distributor was spraying asphalt, the bitumeter was checked daily.

F. Aggregate Spreading Operation. All aggregate needed for the planned spread was on hand or enroute before starting. When the distributor moved forward to spray asphalt, the aggregate spreader followed immediately behind it. The asphalt was covered within one minute. Otherwise, the increase in viscosity that takes place within that time may have prevented good wetting and binding of the aggregate. The aggregate was spread uniformly and at a controled rate. With a single application, aggregate did not stick more than one particle thick to the asphalt, so it was useless and wasteful to apply it at a rate greater than a single layer.

By using a self-propelled spreader, a uniform application rate of 13.5 lbs./sq.yd. was assured with a tachometer used to maintain uniform speed.

Excess aggregate, if placed in some areas, was removed immediately with square-end shovels. In areas where application was insufficient, additional aggregate was added.

G. Aggregate Spreader Data. A self- propelled Etnyer spreader was used to apply the aggregate. This machine moves forward and makes possible a very uniform and continuous application of cover aggregate. It was able to keep up with the asphalt distributor. The spreader was self-powered and had a receiving hopper in the rear. Aggregate trucks were hitched to the spreader, dumped their loads into the hopper, and were pulled by the spreader. Belt conveyors carried the aggregate to the front of the machine where it was dropped into the spreading hopper. Aggregate flowed over a spread roll onto a screen that permitted initial placement of larger particles on the asphalt followed by fine aggregate on top.

H. Rolling Operation. One pneumatic tire roller and one steel wheel (three wheel) roller were used on the job. Rolling with the pneumatic tired roller started almost immediately after the application of the aggregate. The resilient tires on the roller forced the aggregate firmly into the asphalt binder without crushing the stone.

Our contractor did not recommend that a steel wheeled roller be used since it was feared that this roller would crush the aggregate and degradation would take place before traffic used the new surface. But, from our previous years experience, we felt the steel wheel rollers would not crush the stone since trap rock was being used and the secondary rolling with the steel three wheel roller actually helped set the aggregate within the seal coat and minimize whip off after the street was opened to traffic.

During the rolling operation, the tires on the pneumatic tired roller were inspected for proper inflation. The steel wheel roller was inspected with a sharp metal straight edge for wear of the wheel rims. It was also critical that the kingpins did not show signs of slackness and any excessively worn wheel bearings be replaced.

I. Protection of Seal Coat. As described in Section 4.G - Traffic Control Plan, the surface treatment was protected from vehicular traffic by the establishment of a detour during the operation and the control of traffic speed for the first hour or two after the application.

J. Brooming and Other Cleaning Operations. Even though extreme efforts were taken to minimize the loose aggregate on the street after the rolling operation, some of the stone did not stick to the seal coat. Once the street was opened to unrestricted traffic, fast moving vehicles picked up the loose particles and threw them against the vehicle and following vehicles. These vehicles tended to whip the loose aggregate to the gutter line. Stone also accumulated at intersections the first twenty-four hours after the operation, and was removed by Public Works Department personnel using hand booms and shovels.

One to two weeks after the application was completed and after a steady rainfall had occurred, the aggregate that was whipped or washed to the gutter line was collected with the Township's three wheel mechanical street sweeper. The excess stone was stockpiled and will be used during the year to stabilize shoulders.

The first two or three days after the surface treatment application, I received a half a dozen telephone calls from residents not familiar with the precoated chip and emulsion program. They complained of the aggregate whipping up on the inside of the wheel wells of their cars and that the stone was being tracked onto their driveways and into their homes.

I explained that this inconvenience was normal and the steps that would be taken to remove the excess stone by means of the street sweeper once the loose stone was whipped or washed to the gutter. This explanation, plus the fact that compared to the cost of a conventional one inch overlay of ID-2A surface course, the precoated aggregate surface treatment was 75% more economical (i.e., $0.80/sq. yd. for ½" of precoated aggregate vs $3.20/sq. yd. for a one inch overlay) seemed to satisfy the resident's concerns. I concluded my conversation by apologizing for the inconvenience and informed them that within a period of two weeks, if the whipping and tracking of aggregate had not stopped, they were to call my office and I would see that any loose stone would be swept up by hand from the street.

After the two week period, the only telephone call I received was from a previous caller who apologized for his hasty reaction to the surface treatment program and he was now able to realize the benefits of the program.

K. Breaking and Curing Characteristics of the Emulsion. The dispersed fine droplets of asphalt in the emulsion precipitated after contacting the road pavement. The result was the formation of a continuous asphalt film on the surface of pavement, at the location where it was desired. When this physical change or precipitation of dispersed droplets was taking place, the emulsion was "breaking." The water originally present as the dispersing phase evaporated, hastening the formation of the continuous asphalt film. An emulsion would also "break" by the mere loss of water due to evaporation which tends to concentrate the asphalt in the emulsion.

Normally, emulsions contain 25 to 30 percent water. Therefore, when the emulsions set, there was a 25 to 30 percent volume reduction due to evaporation of water. The film collapsed due to this volume change.

Emulsions have the advantage that they can be used with damp aggregate or when the pavement is damp. In fact, damp aggregate was preferred to avoid premature "breaking" (or setting) of the emulsion immediately on contacting the aggregate surface.

In summary, the factors which affected the setting rate of the emulsion in our program were as follows:

(1) Breaking started as soon as emulsion contacted the pavement surface. The "break" of cationic emulsion was speeded by this chemical phenomenon because of the cationic agent.

(2) The rate that water was absorbed by the aggregate affected the time required for emulsions to set.

(3) The pressure from rolling broke the emulsions back to asphalt and held the stone.

(4) The evaporation of water was the primary method which finally caused the emulsions to break.

L. Total Mat Thickness. A recently opened utility trench on one of the streets treated confirmed that the total mat thickness for the surface treatment was ¼" to 5/16" thick.

VI ENERGY CONSUMPTION

A. Energy required to manufacture an asphalt emulsion versus an asphalt cutback was taken from the Asphalt Institute Report IS-173, dated November 1979,

BTU's required to produce one gallon of:

CRS-2 (E-3 Emulsion)	=	2715 BTU's/gallon
RS-1 (E-1 Emulsion)	=	2565 BTU's/gallon
RC-800 (Cutback-Seal Coat)	=	33,800 BTU's/gallon
MC-30 (Cutback-Precoat Aggregate)	=	70,000 BTU's/gallon

In considering the energy required to produce one gallon of asphalt emulsion the following factors were considered: Electrical energy and fuel energy to refine the asphalt; energy to produce the emulsifier and complete the emulsifying process. No energy factor for the production and addition of a solvent was considered since these two types of emulsion are 100% solvent free.

In the case of the asphalt cutbacks, the amount of fuel energy in the added solvent must be considered since the solvent factor for RC-800 is 20% and 40% for MC-30.

B. Fuel (Energy) Consumption during construction is distributed between hauling the stone and asphalt, heating and spraying asphalt, precoating and spreading the aggregate, and rolling the aggregate.

To determine the energy consumed during the hauling of the materials, the FHWA tables showing the distribution of highway travel and fuel consumption by vehicle were used. The loads were adjusted for the load carried and total miles traveled both loaded and empty.

In both the use of emulsions and cutbacks, the energy used to haul the aggregate and the asphalt would be:

Asphalt - 50 miles, haul asphalt to storage tank - 2090 BTU's/gallon

7.5 miles, haul asphalt to job site - 266 BTU's/gallon

Aggregate - 17.5 miles, haul aggregate to job site - 1008 BTU's/square yard

Energy requirements for asphalt spray applications using an asphalt distributor were categorized as follows: (1) heating the asphalt, (2) pumping asphalt through the spray bar, and (3) the truck operation. Heating the asphalt to spraying temperature and maintaining it at that temperature involved the greatest consumption of energy. The amount of time the elevated temperatures were maintained probably had the greatest influence on the energy consumed for this purpose. For the purposes of this report, 400 BTU per gallon was used for heating cutback asphalt to spraying temperatures. For emulsified asphalt, 100 BTU per gallon was used.

Power requirements for pumping units on the asphalt distributor was 35 horsepower and the pumping rate for spraying was 14 gallons per minute per foot of spray bar width. Since the engine was gasoline powered and the distributor sprayed over a ten foot width, the BTU requirement for spraying was

$$\frac{35 \text{ hp} \times 0.75 \text{ @ } 0.06 \text{ gal./hp - hr @ } 125{,}000 \text{ BTU/gal.}}{14 \text{ gal./min/ft.} \times 10 \text{ ft.} \times 60 \text{ min/hr.}} = 21 \text{ BTU/gal.}$$

The distributor was a three-axle rig consuming 4,270 BTU per ton-mile while spraying asphalt over the roadway translates to a little more than 17 BTU/gal. of asphalt sprayed.

For purposes of this report, the energy requirements for asphalt distributor operatons were as tabulated below:

	Cutback Asphalt	Emulsified Asphalt
Heating asphalt	400 BTU/gal	100 BTU/gal
Spraying asphalt	21 BTU/gal	21 BTU/gal
Distributor Truck	17 BTU/gal	17 BTU/gal
Total	438 BTU/gal	138 BTU/gal

Self-propelled aggregate spreader, used for applying seal coat cover aggregate, was powered by an engine having approximately 60 hp. The flow of aggregate per minute was controlled by the hopper opening and forward speed of the spreader. Thus, within limits, the spreader was operated within a desired speed of around 450 feet per minute and cover aggregate was spread over a 10-foot width. The energy requirements per square yard for both emulsion and cutbacks were:

$$\frac{60 \text{ hp} \times 0.75 \text{ @ } 0.06 \text{ gal/hp-hr @ } 125{,}000 \text{ BTU/gal} \times 9 \text{ sf/sy}}{450 \text{ ft per min} \times 60 \text{ min/hr} \times 10 \text{ ft.}} = 10 \text{ BTU/sy}$$

The roller used 4.5 gallons of diesel fuel per hour and three passes were required in a ten foot lane. The average speed of the roller was 3 mph, the area that was covered per hour was:

$$\frac{3 \text{ mph} \times 5{,}280 \text{ ft/min} \times 10 \text{ ft}}{9 \text{ sf/sy} \times 3 \text{ passes}} = 5866 \text{ sy/hr (3 passes)}$$

The energy required for rolling both the emulsion and the cutback was:

$$\frac{4.5 \text{ gal/hr @ } 139{,}000 \text{ BTU/gal}}{5{,}866 \text{ sy/hr-in.}} = 106 \text{ BTU/sy (Call 110 BTU/sy) or } 37 \text{ BTU/sy/pass}$$

C. No electric power was used during the construction.

D. If RC-800 had been used for the seal coat and MC-30 had been used to precoat the aggregate, the following amounts of petroleum distillates would have been required to surface treat 50,000 square yards of streets:

For RC-800 with 20% solvent:

.24 gal/sy x 50,000 sy x 0.20 = 2400 gals. of distillates

For MC-30 with 40% Solvent:

50,000 sy x 13.5 lbs/sy = 338 Tons of Aggregate to Precoat

338 Tons x 2 gals/ton = 676 Gallons

676 gallons x 0.40 = 270 Gallons of distillates

E. Since emulsions require no solvents, the total gallons of petroleum distillates saved by using an E-3 emulsion for a seal coat and an E-1 emulsion to precoat the aggregate is 2400 gallons + 270 gallons or 2670 gallons for our project.

F. The energy saved in lower application temperature with the emulsion is approximately fourfold since cutback asphalts require 400 BTU/gallon to heat the asphalt to spraying temperature while emulsion asphalts require only 100 BTU/gallon.

G. With the E-1 emulsion used to precoat the aggregate, the aggregate still had to be dried prior to the precoating in the pugmill. Therefore, no energy was saved by using the E-1 emulsion instead of the MC-30 cutback. Experimentation has been conducted with an E-8 emulsion to precoat the aggregate which would not require drying of the aggregate and as a result, could save 2450 BTU/sy.

VII COST OF ALTERNATE METHODS

The cost differential between using an emulsion asphalt to seal and precoat the aggregate versus using a cutback asphalt is derived by the savings of energy to produce and heat the asphalt to application temperature. In detail, to produce and apply an asphalt seal coat with precoated aggregate using asphalt cutback would require the following amounts

of energy:

Produce RC-800 cutback	33,800 BTU/gal.
Haul Asphalt to Storage Tank, 50 miles	2,091 BTU/gal.
Haul Asphalt to Job Site, 7.5 miles	266 BTU/gal.
Heat & Spray Asphalt from Distributor	438 BTU/gal.
Subtotal	36,595 BTU/gal.
0.24 gal./sy x 36,595 BTU/gal	8,783 BTU/sy
Produce Aggregate 13.5 lbs./sy x Ton/2000 lbs x 56,000 BTU/Ton =	378 BTU/sy
Precoat Aggregate with MC-30	658 BTU/sy
Haul Aggregate to Job Site, 17.5 miles	1,008 BTU/sy
Spread Aggregate	10 BTU/sy
Rolling, 3 passes @ 37 BTU/sy ea.	110 BTU/sy
Total Energy Required using cutback Asphalt	= 10,947 BTU's/sy
Produce E-3 Emuslion	2,715 BTU/gal.
Haul Asphalt to Storage Tank, 50 miles	2,091 BTU/gal.
Haul Asphalt to Job Site, 7.5 miles	266 BTU/gal.
Heat & Spray Asphalt from Distributor	138 BTU/gal.
Subtotal	5,210 BTU/gal.
0.24 gal./sy x 5,210 BTU/gal.	1,250 BTU/sy
Produce Aggregate	378 BTU/sy
Precoat Aggregate with E-1	38 BTU/sy
Haul Aggregate to Job Site, 17.5 miles	1,008 BTU/sy
Spread Aggregate	10 BTU/sy
Rolling, 3 Passes @ 37 BTU/sy ea.	110 BTU/sy
Total Energy Required using an Emulsion Asphalt	2,794 BTU/sy

The difference in energy required between the two asphalts is:

10,974 BTU/sy - 2,794 BTU/sy = 8,153 BTU/sy

To determine the cost differential, we must first determine the present cost of a BTU of energy. To do this, I will use a No. 2 fuel oil which currently sells for $0.98/gal. No. 2 fuel oil generates 139,000 BTU/gal. at 100% efficiency. Therefore, at 75% efficiency:

1 gal/139,000 BTU (.75) x $.98/gal. = $0.0000094/BTU

8,153 BTU/sy x 50,000 sy/Job x $.0000094/BTU = $3,831.91 Saved by using an Emulsion

VIII ENVIRONMENTAL CONSIDERATIONS

Emulsions are relatively pollution free and they meet most ecology requirements since only water evaporates into the atmosphere. In contrast, cutbacks evaporate volatiles such as hydrocarbons in the air as they cure.

Legislation to control the use of cutbacks as part of the Pennsylvania Department of Environmental Resources "Air Pollution Control Act" was adopted in 1979. Simply stated, the cutback asphalt paving regulation prohibits the use of cutback asphalts for any application except for a penetrating prime coat, a dust palliative, a tack coat or precoating of aggregate between May 1 and October 31 of any year starting in 1980. The regulations permitted the use of emulsion with up to 12% solvent by volume.

Emulsions are safe to use. There is little danger of fire as compared to cutbacks.

Finally, emulsions are applied at a relatively low temperature in comparison to cutbacks. Low operating temperatures mean less repairs, maintenance, and fuel costs for equipment.

Respectfully submitted,

Charles F. Oyler, P. E.
Director of Public Works
Plymouth Township
November 26, 1980

BEST DOCUMENT AVAILABLE

FIG. 1 GRADATION CHART

DISTRICT_____ COUNTY_____ L.R._____ SECTION_____

AGGREGATE TYPE_____ SUPPLIER_____

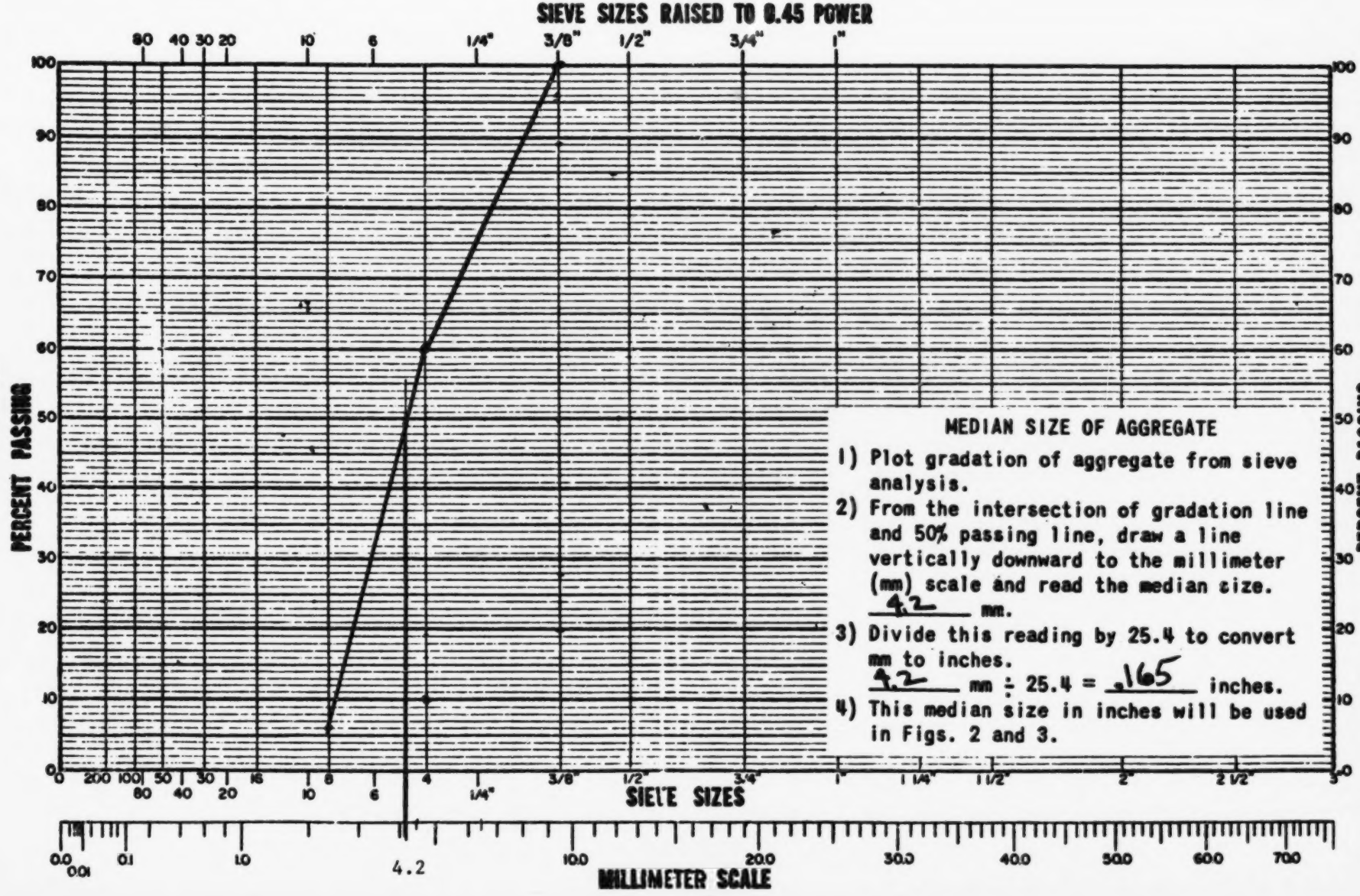

SIEVE SIZES RAISED TO 0.45 POWER
80 40 30 20 10 6 1/4" 3/8" 1/2" 3/4" 1"
PERCENT PASSING
100 90 80 70 60 50 40 30 20 10 0
200 100 80 50 40 30 20 16 10 8 6 4 1/4" 3/8" 1/2" 3/4" 1" 1 1/4" 1 1/2" 2" 2 1/2" 3"
SIEVE SIZES
0.0 0.001 0.1 1.0 4.2 10.0 20.0 30.0 40.0 50.0 60.0 70.0
MILLIMETER SCALE
MEDIAN SIZE OF AGGREGATE
1) Plot gradation of aggregate from sieve analysis.
2) From the intersection of gradation line and 50% passing line, draw a line vertically downward to the millimeter (mm) scale and read the median size. 4.2 mm.
3) Divide this reading by 25.4 to convert mm to inches. 4.2 mm ÷ 25.4 = .165 inches.
4) This median size in inches will be used in Figs. 2 and 3.

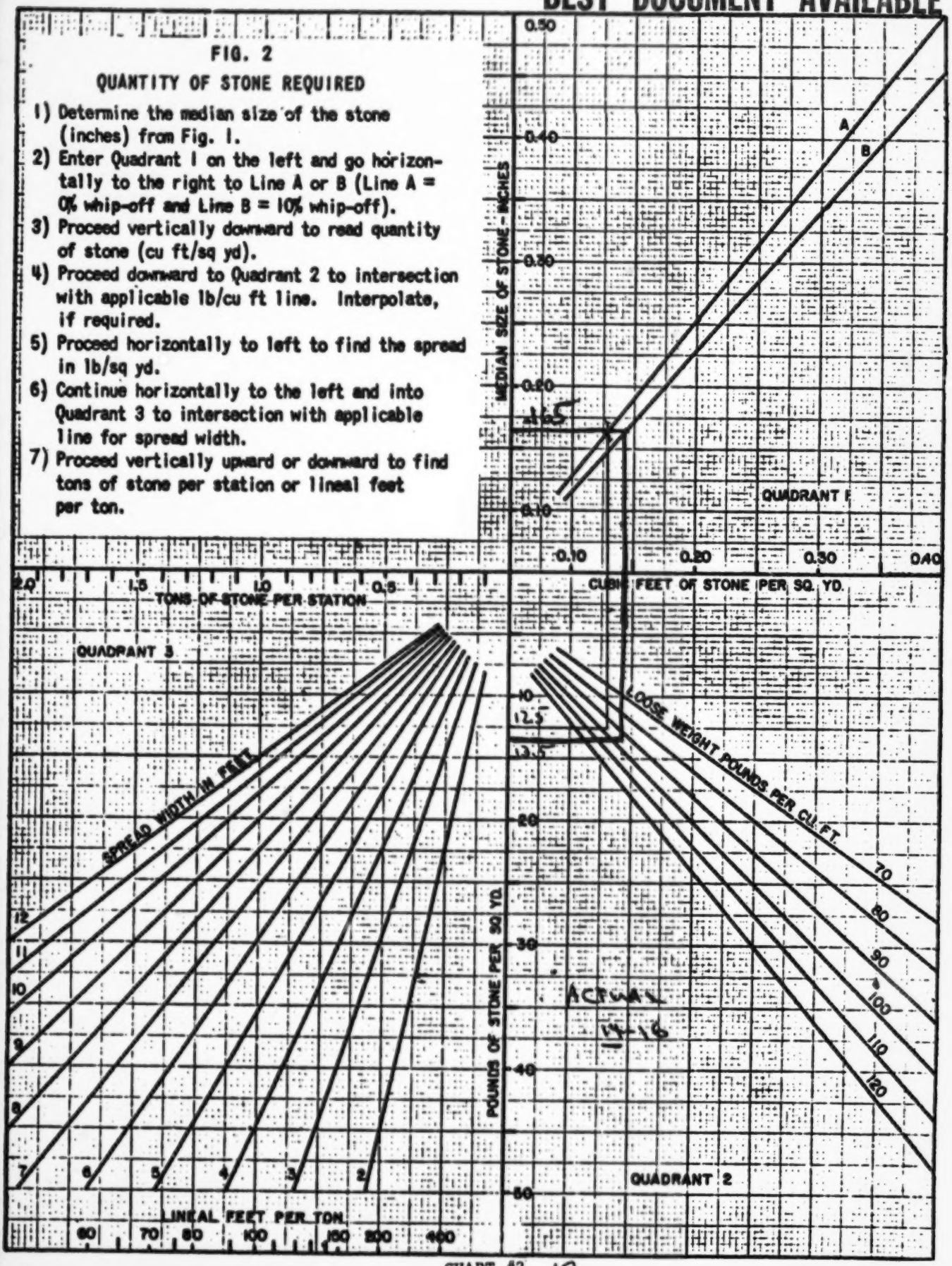
CHART #1

BEST DOCUMENT AVAILABLE

FIG. 2

QUANTITY OF STONE REQUIRED

1) Determine the median size of the stone (inches) from Fig. 1.
2) Enter Quadrant 1 on the left and go horizontally to the right to Line A or B (Line A = 0% whip-off and Line B = 10% whip-off).
3) Proceed vertically downward to read quantity of stone (cu ft/sq yd).
4) Proceed downward to Quadrant 2 to intersection with applicable lb/cu ft line. Interpolate, if required.
5) Proceed horizontally to left to find the spread in lb/sq yd.
6) Continue horizontally to the left and into Quadrant 3 to intersection with applicable line for spread width.
7) Proceed vertically upward or downward to find tons of stone per station or lineal feet per ton.



BEST DOCUMENT AVAILABLE

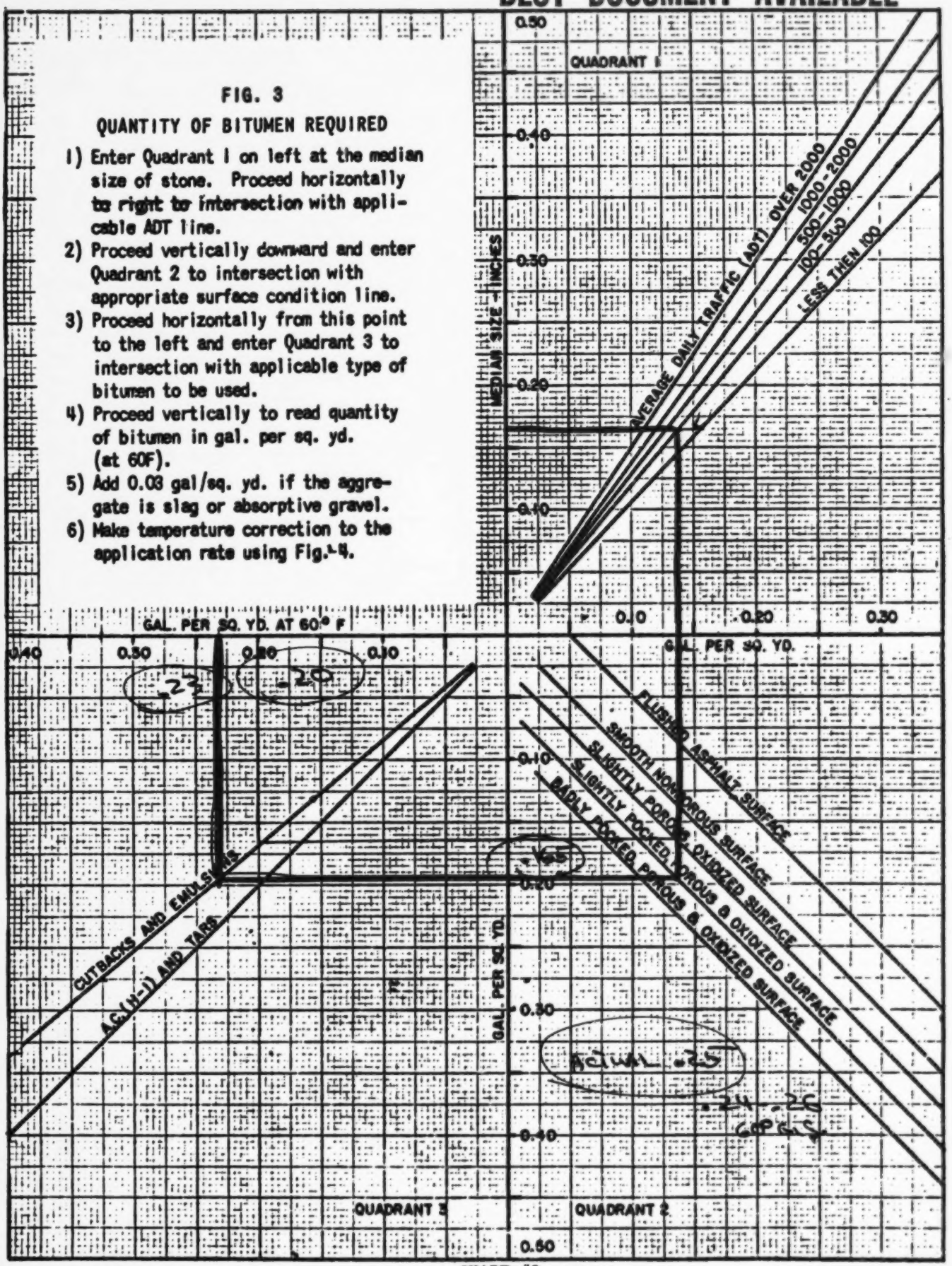


FIG. 3
QUANTITY OF BITUMEN REQUIRED
1) Enter Quadrant 1 on left at the median size of stone. Proceed horizontally to right to intersection with applicable ADT line.
2) Proceed vertically downward and enter Quadrant 2 to intersection with appropriate surface condition line.
3) Proceed horizontally from this point to the left and enter Quadrant 3 to intersection with applicable type of bitumen to be used.
4) Proceed vertically to read quantity of bitumen in gal. per sq. yd. (at 60F).
5) Add 0.03 gal/sq. yd. if the aggregate is slag or absorptive gravel.
6) Make temperature correction to the application rate using Fig. 4.
QUADRANT 1
MEDIAN SIZE - INCHES
0.50
0.40
0.30
0.20
0.10
AVERAGE DAILY TRAFFIC (ADT) OVER 2000
1000-2000
500-1000
100-500
LESS THEN 100
0.0
0.20
0.30
GAL. PER SQ. YD.
GAL. PER SQ. YD. AT 60° F
0.40
0.30
0.20
0.10
.23
.20
.25
.24-.26
CUTBACKS AND EMULSIONS
A.C. (H-1) AND TARS
FLUSHED ASPHALT SURFACE
SMOOTH NON-POROUS SURFACE
SLIGHTLY POROUS, OXIDIZED SURFACE
SLIGHTLY POCKED, POROUS & OXIDIZED SURFACE
BADLY POCKED, POROUS & OXIDIZED SURFACE
Actual
QUADRANT 3
QUADRANT 2
0.50

CHART #3 20

BEST DOCUMENT AVAILABLE

EXAMPLE NO. 1

FIG. 4 TEMPERATURE GALLONAGE CONVERSION CHART FOR BITUMINOUS SURFACE TREATMENT APPLICATIONS

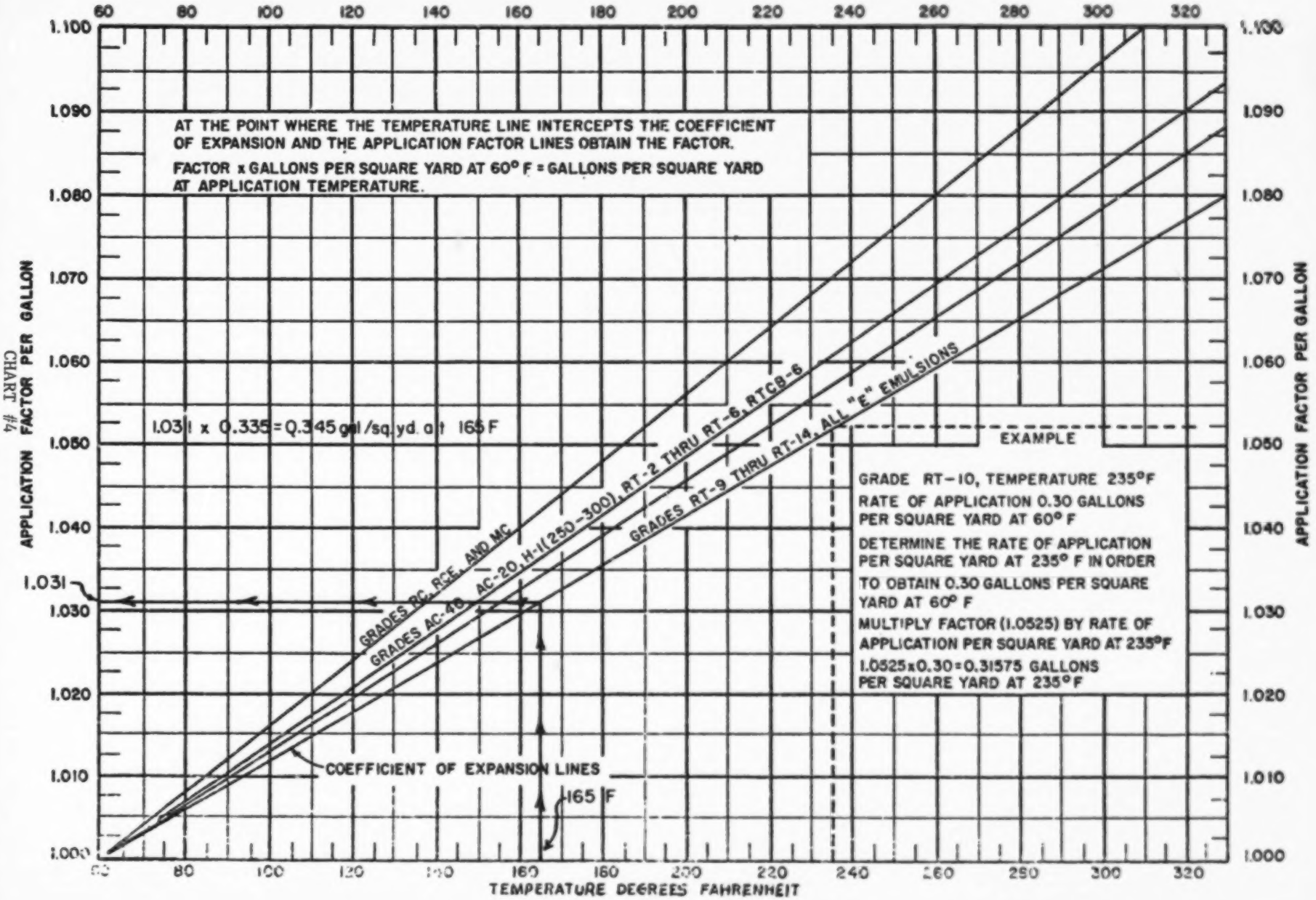

AT THE POINT WHERE THE TEMPERATURE LINE INTERCEPTS THE COEFFICIENT OF EXPANSION AND THE APPLICATION FACTOR LINES OBTAIN THE FACTOR.
FACTOR x GALLONS PER SQUARE YARD AT 60° F = GALLONS PER SQUARE YARD AT APPLICATION TEMPERATURE.
1.031 x 0.335 = 0.345 gal/sq.yd. at 165 F
EXAMPLE
GRADE RT-10, TEMPERATURE 235°F
RATE OF APPLICATION 0.30 GALLONS PER SQUARE YARD AT 60° F
DETERMINE THE RATE OF APPLICATION PER SQUARE YARD AT 235° F IN ORDER TO OBTAIN 0.30 GALLONS PER SQUARE YARD AT 60° F
MULTIPLY FACTOR (1.0525) BY RATE OF APPLICATION PER SQUARE YARD AT 235°F
1.0525 x 0.30 = 0.31575 GALLONS PER SQUARE YARD AT 235° F
GRADES RC, RCE, AND MC
GRADES AC-40, AC-20, H-1 (250-300), RT-2 THRU RT-6, RTCB-6
GRADES RT-9 THRU RT-14, ALL "E" EMULSIONS
COEFFICIENT OF EXPANSION LINES
165 F
APPLICATION FACTOR PER GALLON
TEMPERATURE DEGREES FAHRENHEIT
1.100
1.090
1.080
1.070
1.060
1.050
1.040
1.031
1.030
1.020
1.010
1.000
60
80
100
120
140
160
180
200
220
240
260
280
300
320

CHART #4

BEST DOCUMENT AVAILABLE

EXHIBIT "A

SPECIFICATIONS

ITEM NO. 1: ID-2A Bituminous Surface Course - 400 tons more or less.

ITEM NO. 2: PSP - 100 tons more or less.

ITEM NO. 3: Black Base - 300 tons more or less.

The materials shall meet all requirements as specified in the Pennsylvania Department of Transportation Bulletin 25 Specifications for Bituminous Materials and Form 408 Specifications.

Bid price F. O. B. mixing batch plant.

Bidder shall have the right to increase the contract unit price in an amount equal to the bidder's increase in costs of materials and supplies occurring subsequent to the date on which such bid is submitted (hereinafter referred to as "base date") to the Board having authority to award contracts. Any increase (or decrease) in the bidder's cost of materials and supplies after the base date shall be verified by proper documents furnished to the responsible awarding board which shall include proof of price to the bidder from the bidder's source of supply. Should the bidder's allocation of any item be materially reduced by the bidders source of supply, the bidder may reduce proportionately the quantity of such item to be delivered in accordance with this bid.

ITEM NO. 4: Oil and Precoated Chip - 40,000 square yards more or less.

DESCRIPTION. This work shall consist of an application of bituminous binder material immediately followed by an application of precoated aggregate in accordance with these specifications.

MATERIALS

(a) Bituminous Precoating Material. The precoating material shall conform to the applicable requirements of Bulletin No. 25 and shall be the following:

Class of Material	Type of Material	Application Temperatures Min. F	Min. C	Max. F	Max. C
E-1	Emulsified Asphalt	70	(21)	150	(66)

(b) Bituminous Material. The bituminous material shall conform to the applicable requirements of Bulletin No. 25 and shall be the following:

Class of Material	Type of Material	Application Temperatures Min. F	Min. C	Max. F	Max. C
E-3	Emulsified Asphalt	140	(60)	175	(79)

Cut back asphalt or emulsified cut back asphalt shall be chemically treated with a prepared additive as specified in Bulletin No. 25. All bituminous material shall be heated within the required temperature range, but not in excess of the maximum temperature specified for the class of material used.

(c) Course Aggregate. The coarse aggregate shall be Type A stone, gravel or slag, meeting the requirements of Section 703.3 of the PennDOT 408 for 1/4 inch stone. Thin and elongated pieces shall not be more than 15 percent.

(d) Preparation of Precoated Aggregate

1. The aggregate shall be dried in a batch or continuous type asphalt plant. It shall be precoated in the pug mill.

BEST DOCUMENT AVAILABLE

2. The amount of precoating material shall be 0.5 to 1.0 percent by weight of the mix. The selected rate shall be just sufficient to precoat the particles with a thin film of bitumen. The precoated material shall be free flowing so that it can be stocked, handled, and uniformly spread by a self-propelled spreader. The mixed material shall be stocked no higher than four feet (1.2m) and shall be turned over if necessary to prevent any heat buildup.

3. The temperature of aggregate before mixing shall not exceed 150°F. (66c). The mixing time in the pug mill shall be 30 seconds minimum.

CONSTRUCTION REQUIREMENTS

(a) Conditioning of Existing Surface. The existing surface shall be conditioned in accordance with Section 401.3 (f) of the PennDOT 408, exclusive of the asphalt painting and tack coat operations.

(b) Application of Bituminous Material. No bituminous material shall be applied unless the entire surface is in condition to permit satisfactory penetration and adhesion, and the air, surface, and aggregate temperatures are 50° F (10c) or above. No emulsified asphalt shall be applied if rain is imminent or if freezing temperatures are expected within 24 hours after construction.

The bituminous material shall be uniformly applied by an approved pressure distributor meeting the requirements of Section 441.3 (d), at a rate of 0.20 to 0.50 gallon per square yard (0.63 to 1.58 liters/square meter). Proper rate of application within this range shall be with ± 10 percent the design rate determined by the Pennsylvania Design Method for Seal Coats and surface Treatments as given in Bulletin No. 27.

For areas inaccessible to the distributor, the bituminous material shall be spread uniformly over the surface with approved portable pressure units. The quantity of material to be placed at one time shall be gaged according to the facilities for handling, spreading, and rolling the coarse aggregate as well as temperature of the surface and the bituminous material.

(c) Spreading the Coarse Aggregate and Rolling. Immediately following the application of bituminous material 15 to 30 pounds per square yard (5.6-11.3 k/m^2) of 1/4 inch stone precoated aggregate shall be uniformly spread by a mechanical spreader and rolled with a combination of an approved steel wheel and pneumatic-tired roller or two or more pneumatic-tired rollers until the aggregate is set. Proper rate of application of No. 1B coarse aggregate within the above range, shall be determined by the Pennsylvania Design Method of Seal Coats and Surface Treatments as given in Bulletin No. 27 and shall be strictly adhered to. The surface shall be allowed to cure until it becomes tacky and then back rolled with the pneumatic roller until good adhesion is attained.

(d) Protection of Seal Coat. Traffic shall not be permitted on the newly completed seal coat until adequate stability and adhesion have been attained and the material is sufficiently cured to prevent distortion, flushing of bituminous material to the surface, or loss of aggregate. The contractor shall maintain the treated surface as provided in Section 104.04 (c). The engineer may require that the surface be swept with a power broom to remove any loose chips in the period from seven to fourteen days after application.

BASIS OF PAYMENT

Materials to be delivered and applied as directed on several Township streets within Plymouth Township within ninety calendar days after the award of the contract.

*U.S. Government Printing Office : 1982 - 367-465/645